9x15 Low Speed Wind Tunnel Acoustic Improvements

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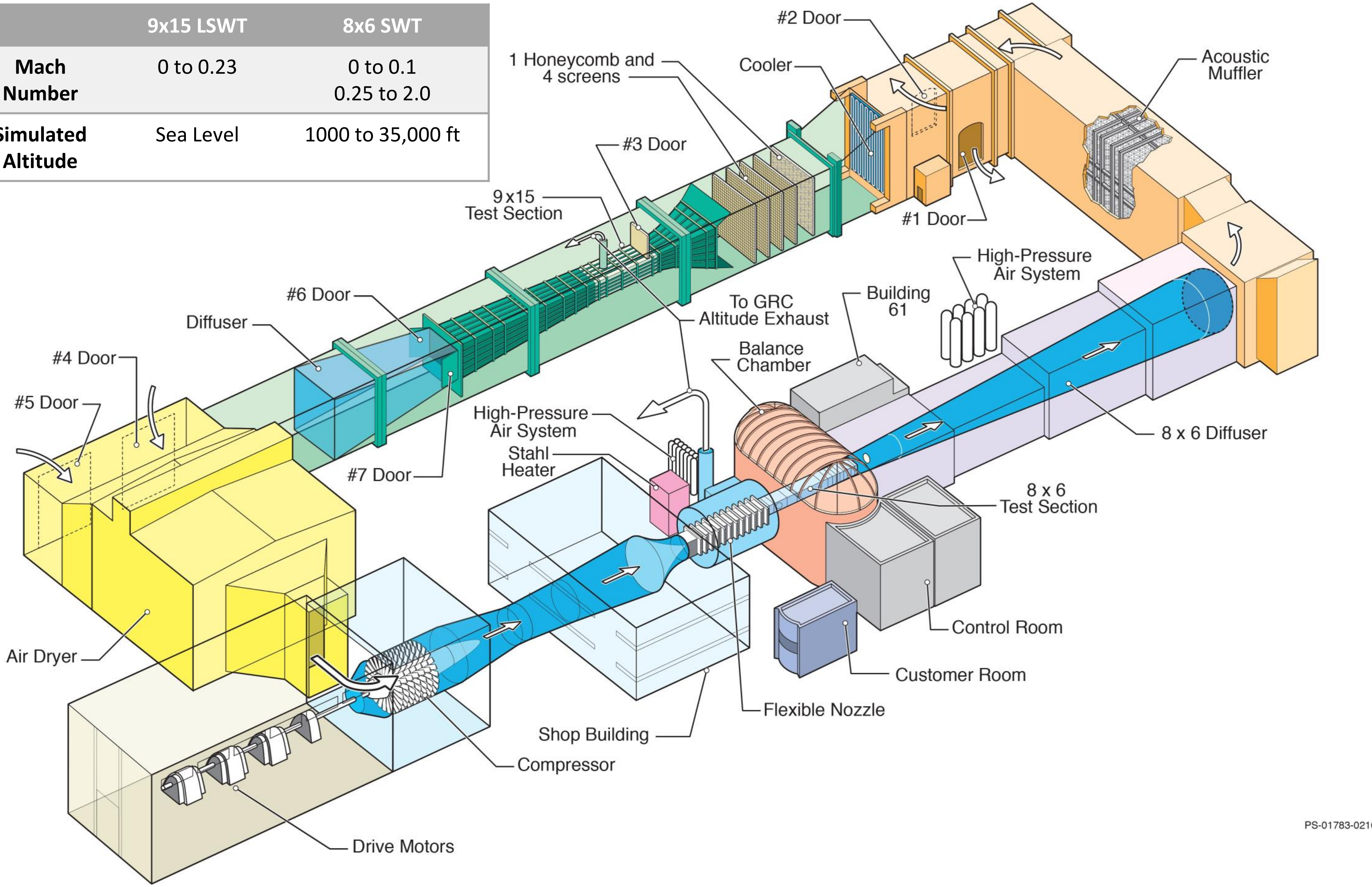
Executive Summary

The 9- by 15-Foot Low Speed Wind Tunnel (9x15 LSWT) at NASA Glenn Research Center was built in 1969 in the return leg of the 8- by 6-Foot Supersonic Wind Tunnel (8x6 SWT). The 8x6 SWT was completed in 1949 and acoustically treated to mitigate community noise issues in 1950. This treatment included the addition of a large muffler downstream of the 8x6 SWT test section and diffuser.

The 9x15 LSWT was designed for performance testing of V/STOL aircraft models, but with the addition of the current acoustic treatment in 1986 the tunnel been used principally for acoustic and performance testing of aircraft propulsions systems. The present document describes an anticipated acoustic upgrade to be completed in 2017.

Unique facility for testing propulsors

	9x15 LSWT	8x6 SWT
Mach Number	0 to 0.23	0 to 0.1 0.25 to 2.0
Simulated Altitude	Sea Level	1000 to 35,000 ft



Fan/Propulsor Testing in 9x15 Tunnel

- The GRC 9x15 Low Speed Wind Tunnel has been extensively used to study and acoustically characterize nearly all of the NASA/Industry propulsor concepts over the past 20 years.

- Except for maintenance, the acoustic treatment has remained essentially unchanged in 20+ years.

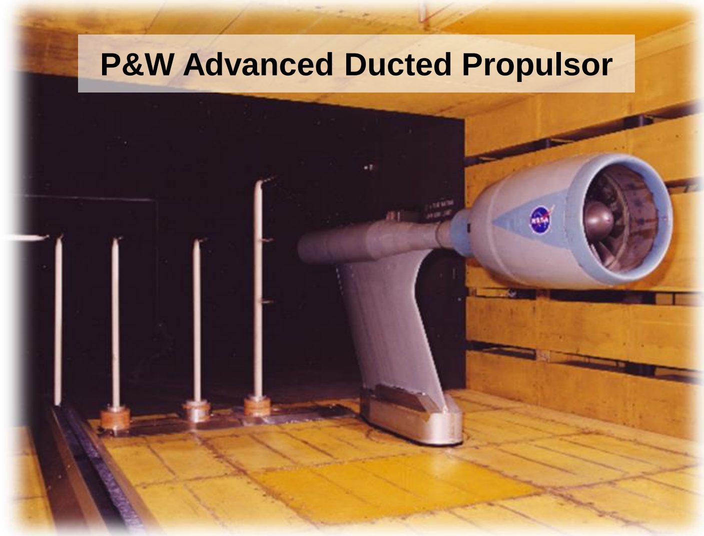
Honeywell Turbofan with Acoustic Liners

P&W Geared Turbofan

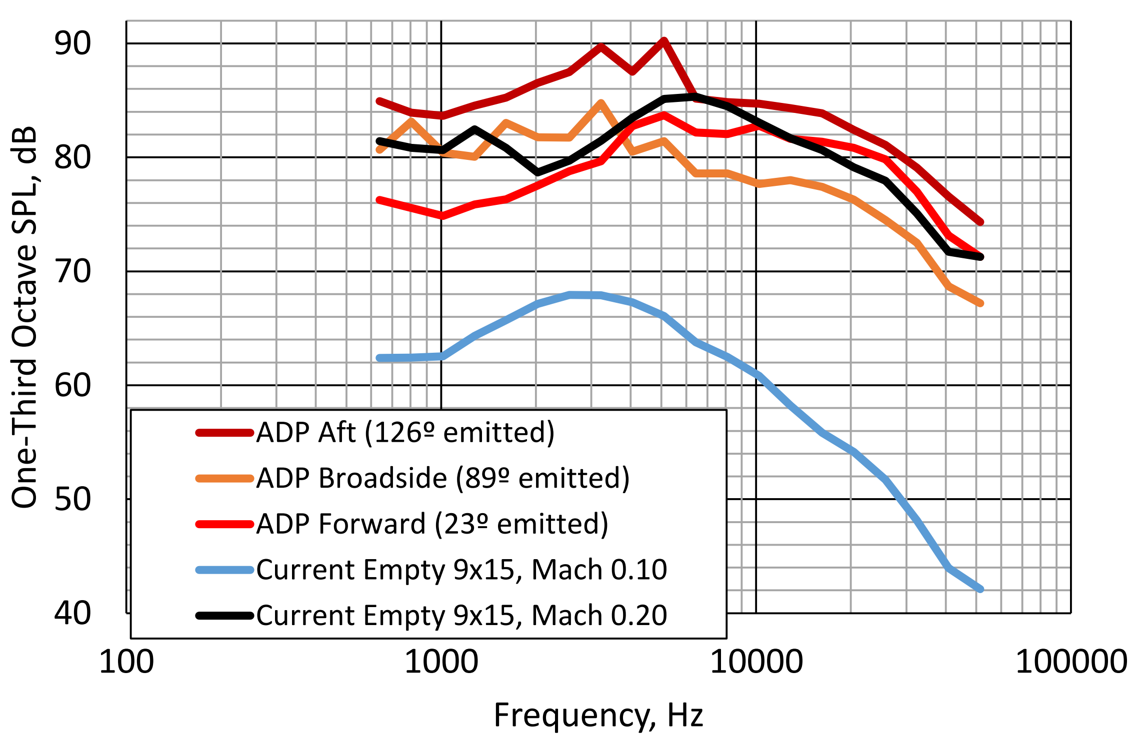

NASA/GE Open Rotor

Testing quiet fans requires a quiet wind tunnel

- Historically this has been done by testing a Mach 0.1, which is below true take-off and landing speeds.



Empty 9x15 vs Low Power ADP with Liners



- Future fans may be even quieter
  - Low tip speed
  - Low pressure ratio
  - Acoustic liners
- Open rotors and other concept fans require testing at higher tunnel speeds than Mach 0.1

Support from NASA Agency and Center Levels

- Preliminary assessment by Jacobs Technology, Inc performed in 2012
  - Funded by Environmentally Responsible Aviation
- Initial FY15 NASA funding resulted in initiation of 9x15 Design contract that resulted in completion of a 30% design review.
- Additional funding in FY15 from NASA GRC, NASA AETC project and NASA Augmentation funded a 9x15 Design/Build contract which began in September 2015 from the 30% design point. The FY15 funding provided 60% of the total project Design/Build cost.
- FY16 funding from NASA GRC and NASA AETC is currently being approved by Congress through the FY16 NASA Operating Plan and this funding will provide the remaining 9x15 Design/Build funding.

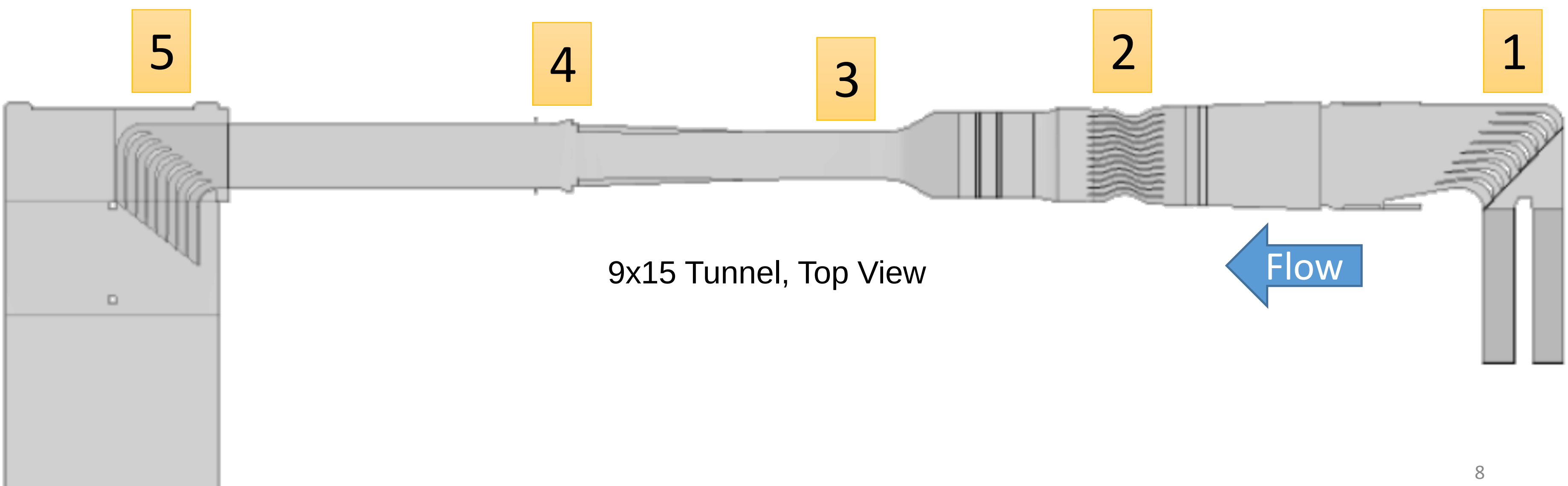
Anticipated Schedule

- December 2015 – Final pre-construction aerodynamic calibration of 8x6 and 9x15 test sections
- January 2016 – Final pre-construction background noise measurement of 9x15 test section
- September 30, 2016 – Boundary layer ingestion test in 8x6 tunnel ends
- October 31, 2016 – Wind Tunnel Shutdown for Start of Site Work
  - Both 8x6 and 9x15 shut down
- September 4, 2017 – Acceptance Testing Begins
  - Acceptance testing for 8x6 and 9x15 test sections
- September 29, 2017 – Tunnel Ready for Testing

Planned Wind Tunnel Renovation

Complementary but discrete improvements

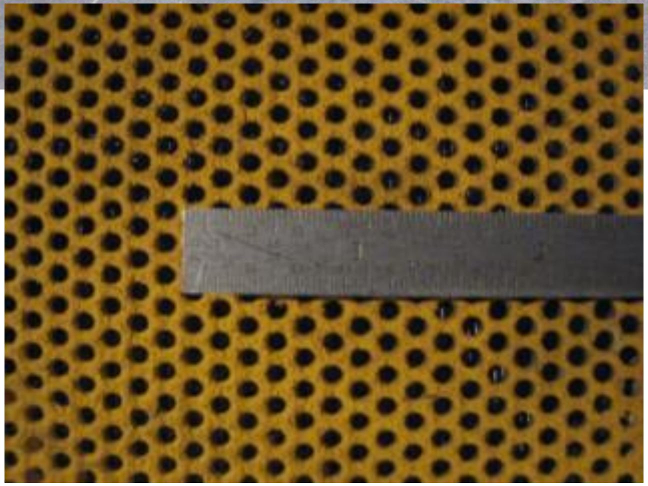
1. Add fairings and turning vanes to turn 2
2. Add acoustic baffles downstream of doors 1 & 2
3. Replace test section flow surfaces, remove slots
4. Reshape diffuser and add acoustic treatment
5. Add turning vanes to turn 3



9x15 Tunnel, Top View

Current 9x15 Test Section

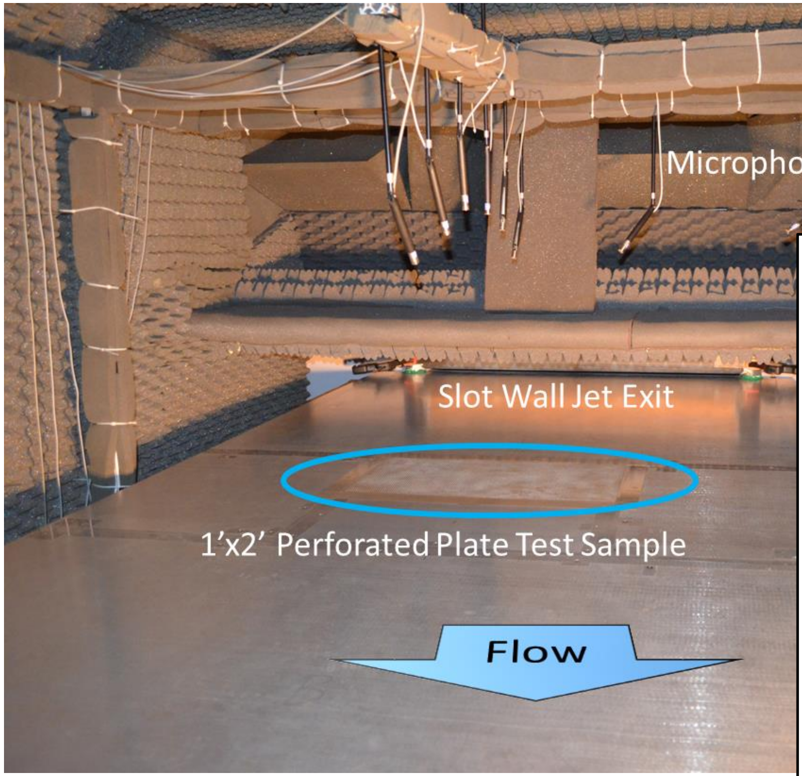
- The test section surface is perforated steel over a bulk Kevlar absorber
  - Facing plate is 16 ga, 1/8” holes, 40 percent open
- The acoustic treatment is built as dozens of individual boxes
  - There are slots in both walls, and many seams throughout the tunnel
- The 2012 study by Jacobs concluded that the majority of the noise in the 9x15 test section above 2 kHz is due to boundary layer flow over perforated steel surface



Test Section Perforated Metal (Current)

Test Section Acoustic Treatment Replacement

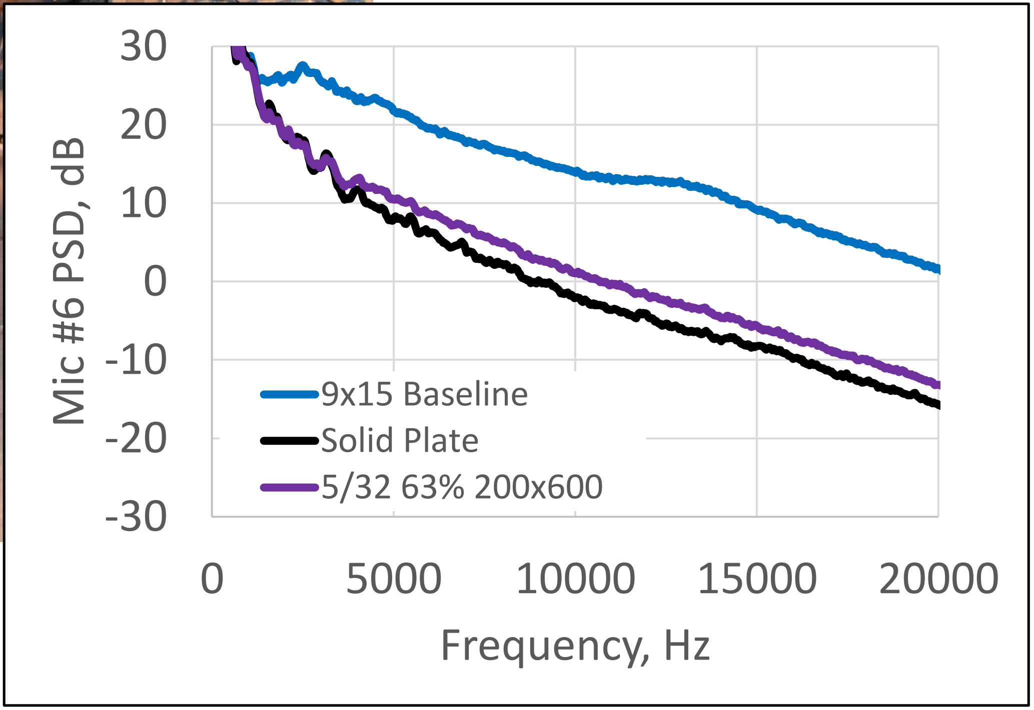
Roughness Noise Facility at Virginia Tech



For more information, see AIAA-2015-3261

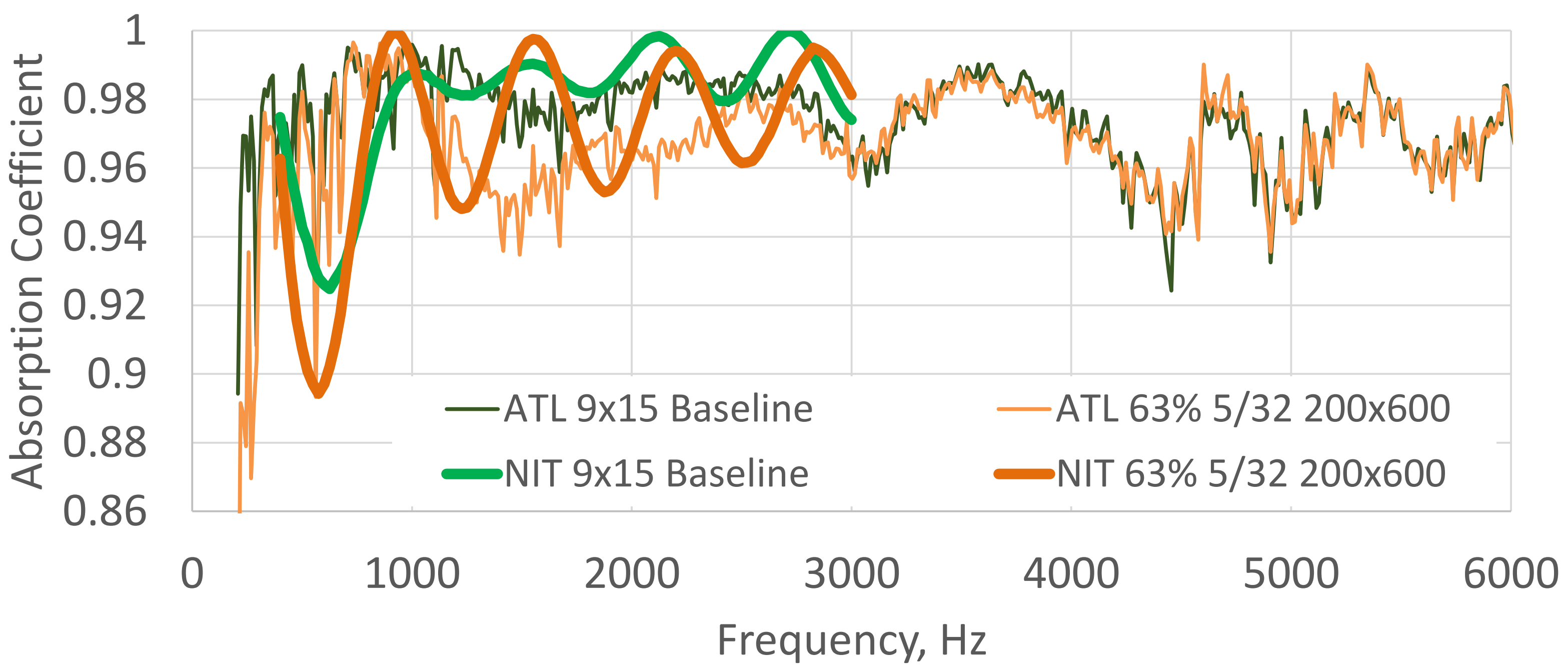
The most significant improvement comes from replacing the flow surface with a micronic wire cloth

Two dozen candidates panels screened



Minimal impact to anechoic quality

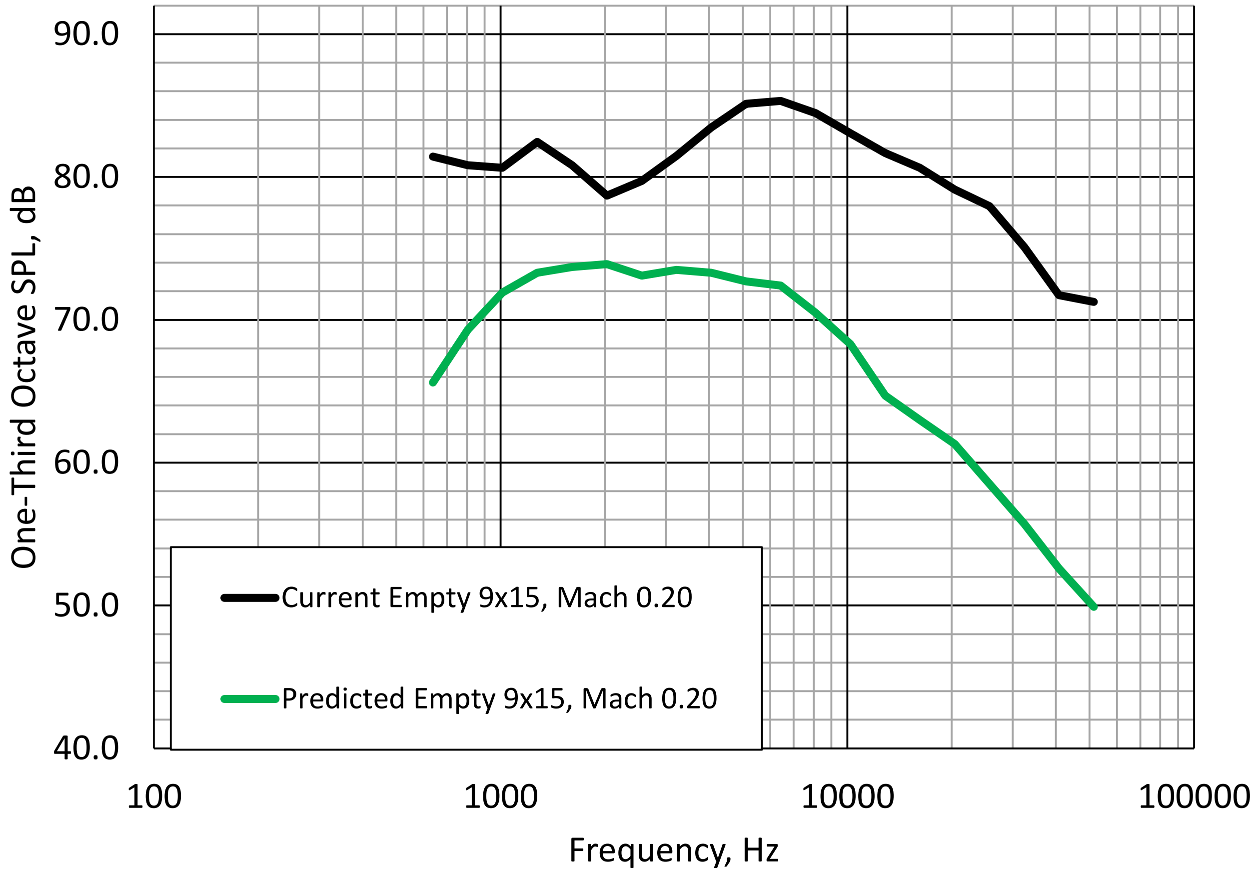
- Impact of wire cloth over perforate has been investigated at LaRC Normal Incidence Tube, LaRC Curved Duct Test Rig and Glenn Acoustical Testing Laboratory



- Anechoic quality of test section to be assessed by external contractor according to ISO 26101

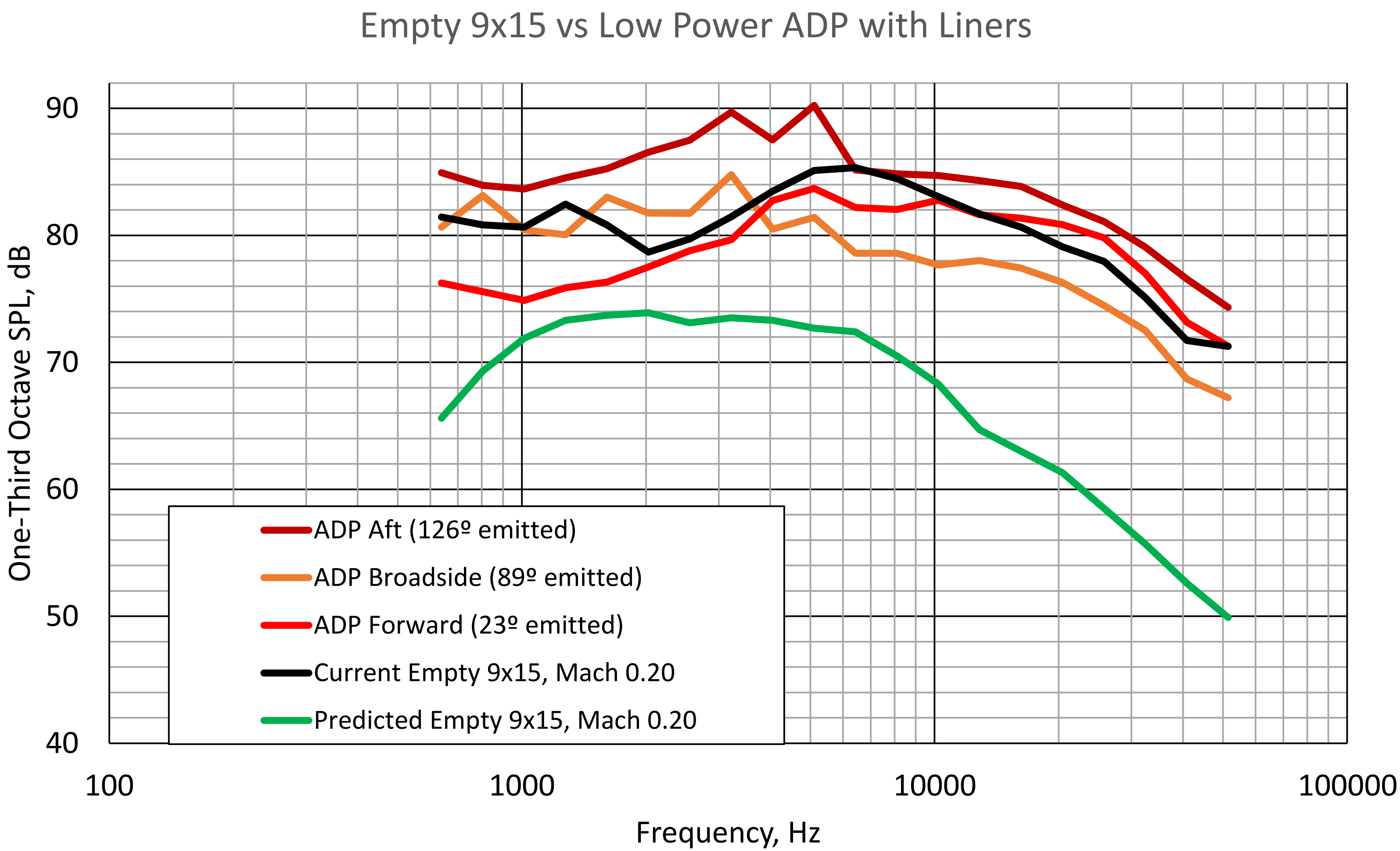
Anticipated Improvement to 9x15 noise levels after all 5 upgrades

Frequency	Empty Tunnel, (2012)	Jacobs Prediction
630	81.2	65.6
794	80.6	69.3
1000	80.5	71.9
1260	82.2	73.3
1587	80.6	73.7
2000	78.5	73.9
2520	79.4	73.1
3175	81.0	73.5
4000	82.8	73.3
5040	84.3	72.7
6350	84.2	72.4
8000	83.1	70.5
10079	81.2	68.3
12699	79.3	64.7
16000	77.8	63.0
20159	76.2	61.3
25398	75.6	58.5
32000	72.6	55.7
40317	66.3	52.6
50797	62.4	49.9



Acceptance criteria: No less than 3 dB from prediction

Relative to P&W Advanced Ducted Propulsor (ADP) Model Fan Measurements



A-Weighted Noise Levels

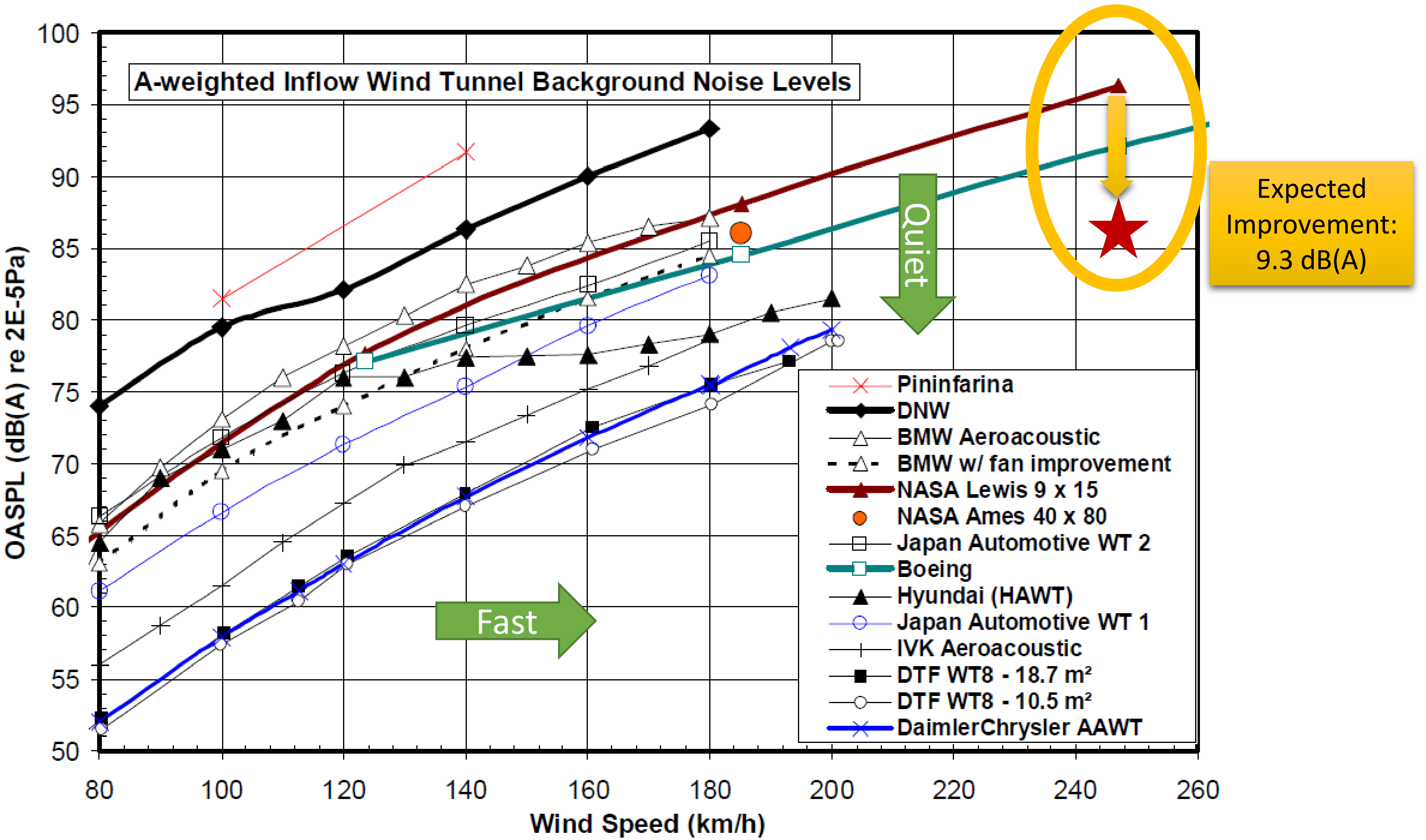
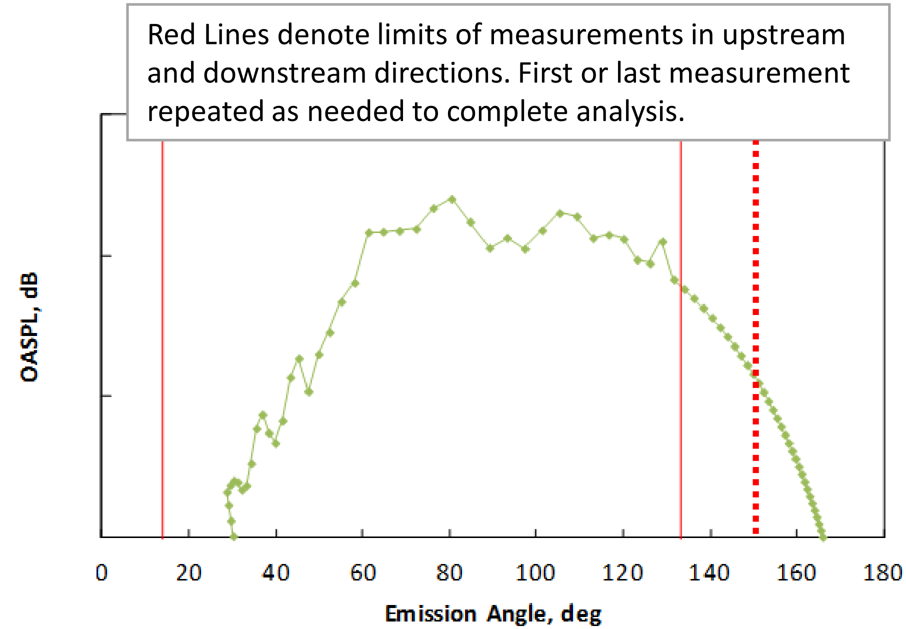
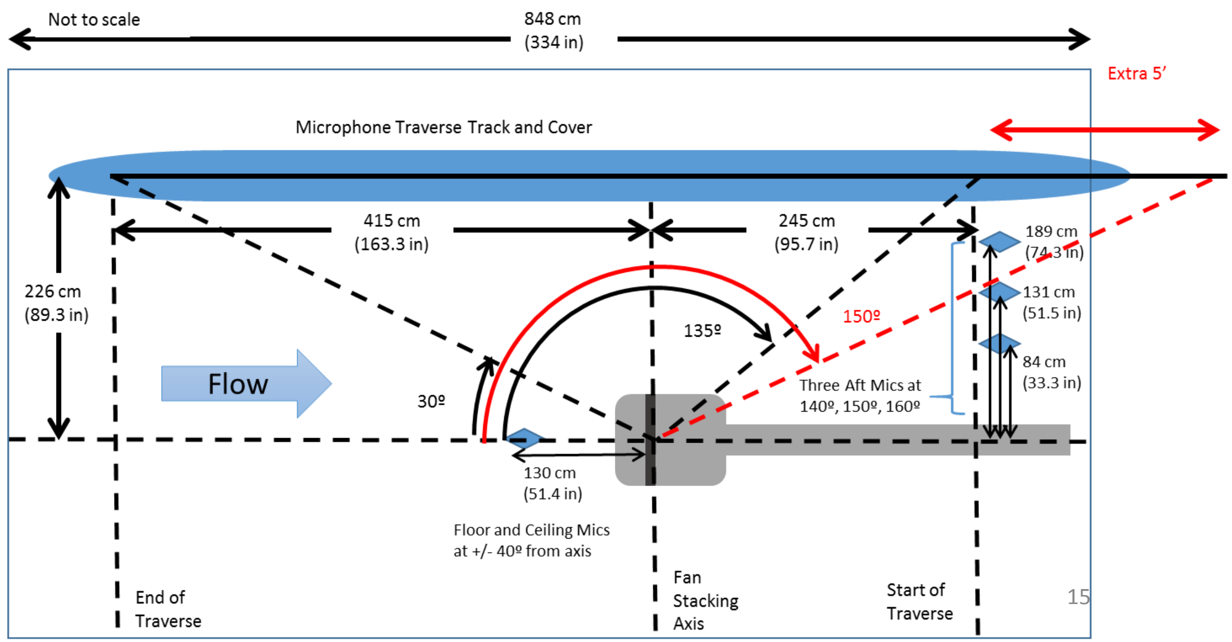


Figure from: AIAA 2002-2503 - *Recent Advances in Large-Scale Aeroacoustic Wind Tunnels*
Edward Duell, Joel Walter, Steve Arnette, Joseph Yen. Sverdrup Technology, Inc.

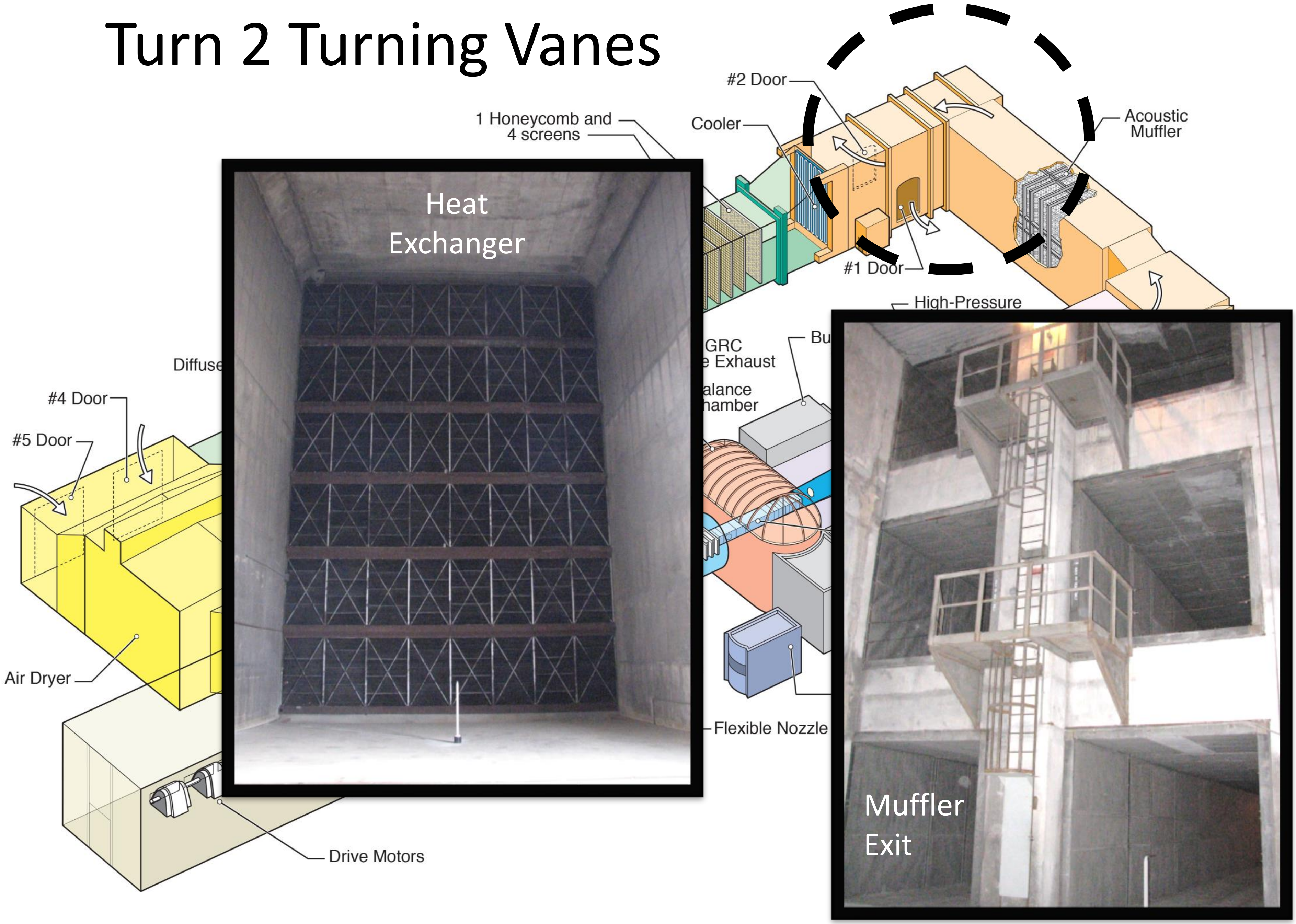
Test Section to be lengthened 5-feet into diffuser

- Current test section length restricts aft measurement angles
- Floor mounted microphones are a marginal solution
- This can have a significant impact on EPNL calculations
- The addition of a 5-foot straight extension into the current diffuser will enable measurement to 150º geometric from upstream

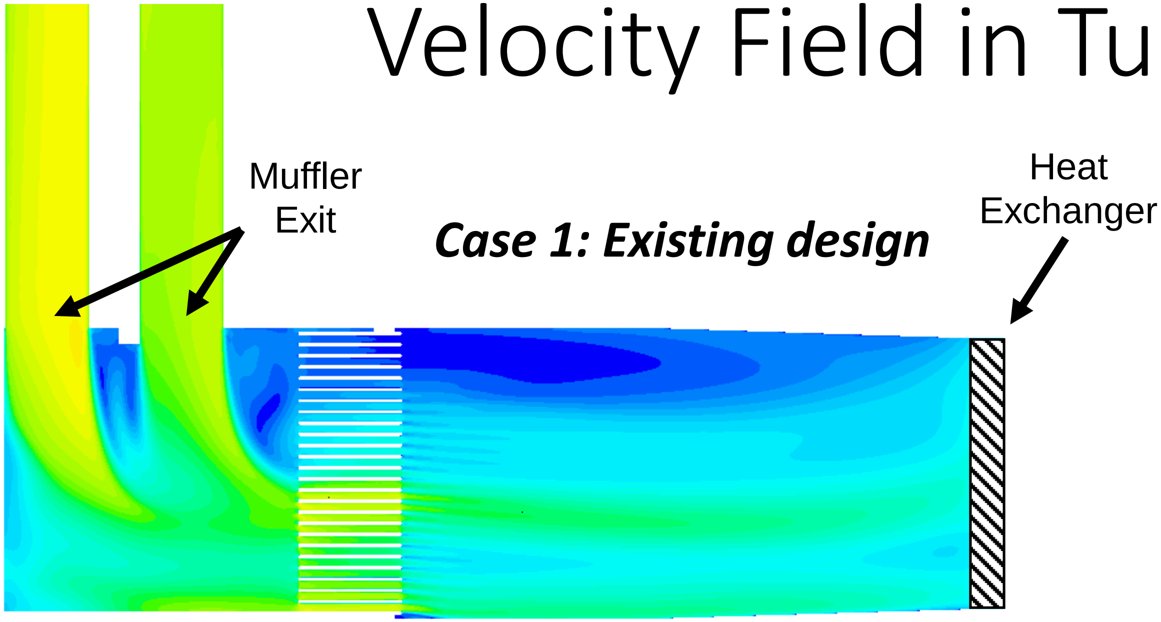


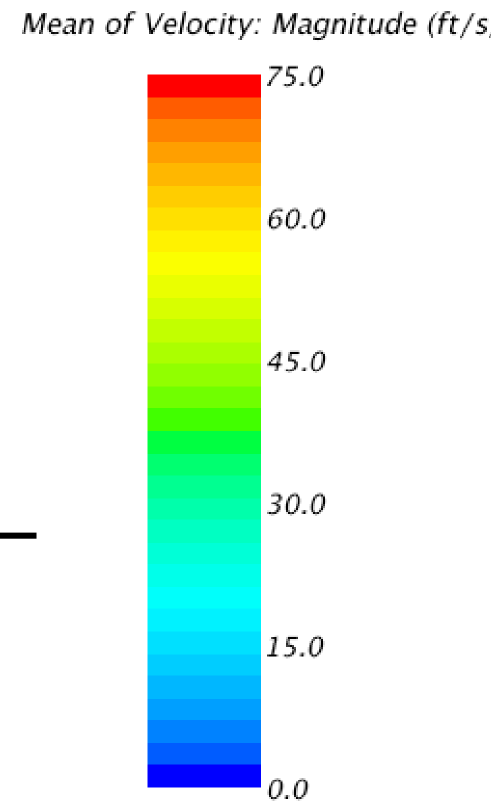


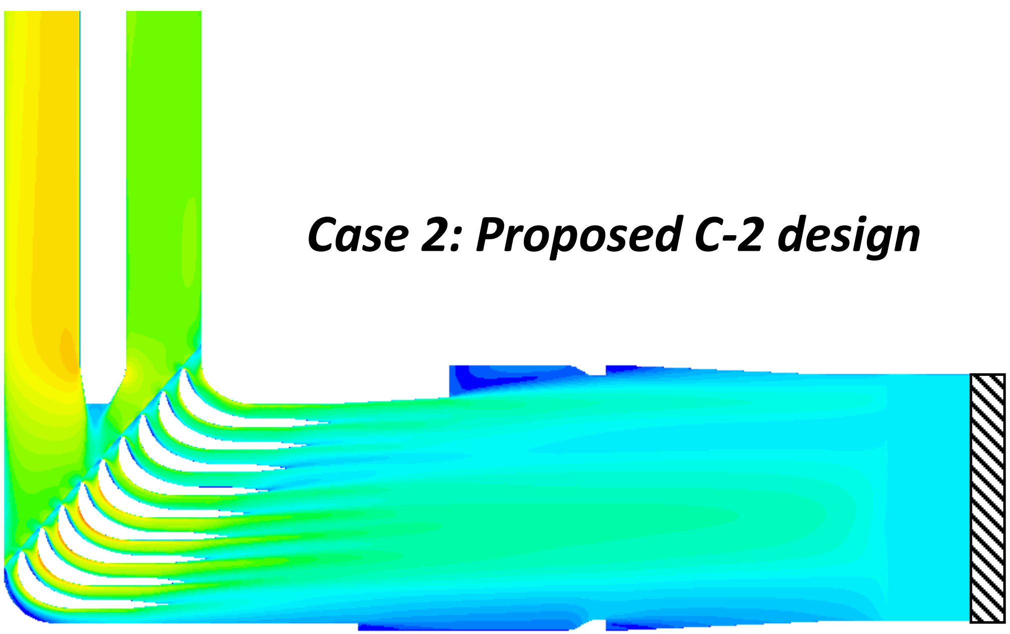
Turn 2 Turning Vanes



Velocity Field in Turn 2







Proposed designs provides much more uniform airflow into cooler.

This should result in more uniform temperature in the test section.

Summary

- GRC responding to industry feedback on 9x15 background noise level requirements
- Design and build contract in place to implement changes to 9x15 for improvements and funding identified and going through approvals
- The work to date by suggests substantial reductions in background that will improve signal-to-noise required in future systems
- Additional work on measurement and signal processing are expected to create additional signal-to-noise headroom